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Remote Sensing for Atmospheric Evidence of Martian Habitability and Habitancy

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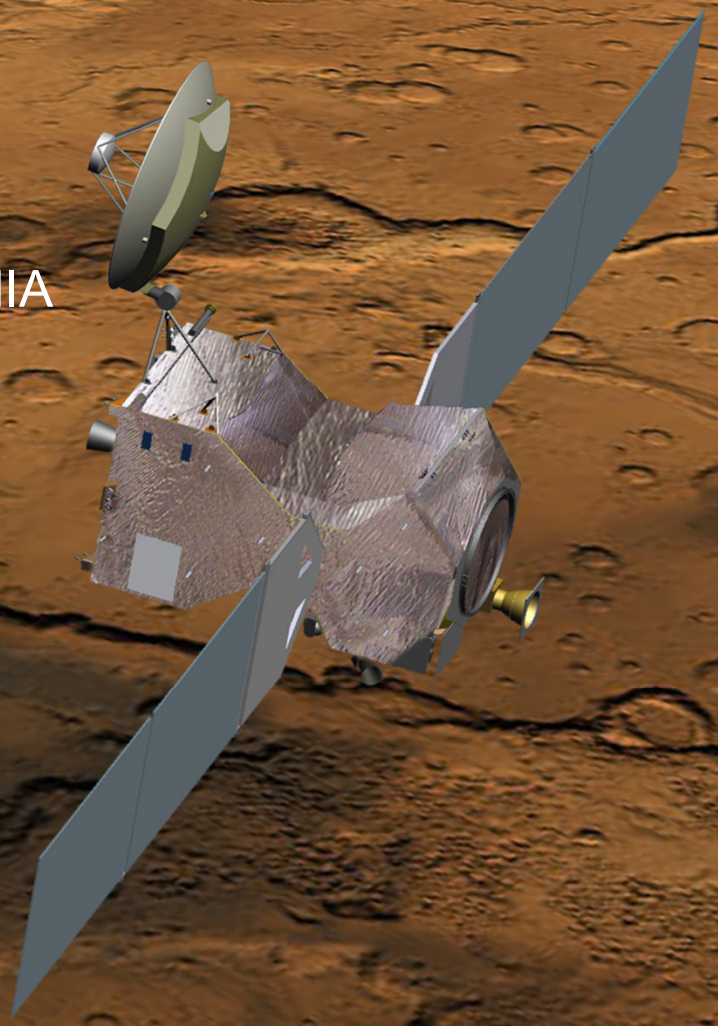

ACS National Meeting
August 30, 2011

Is Mars alive?

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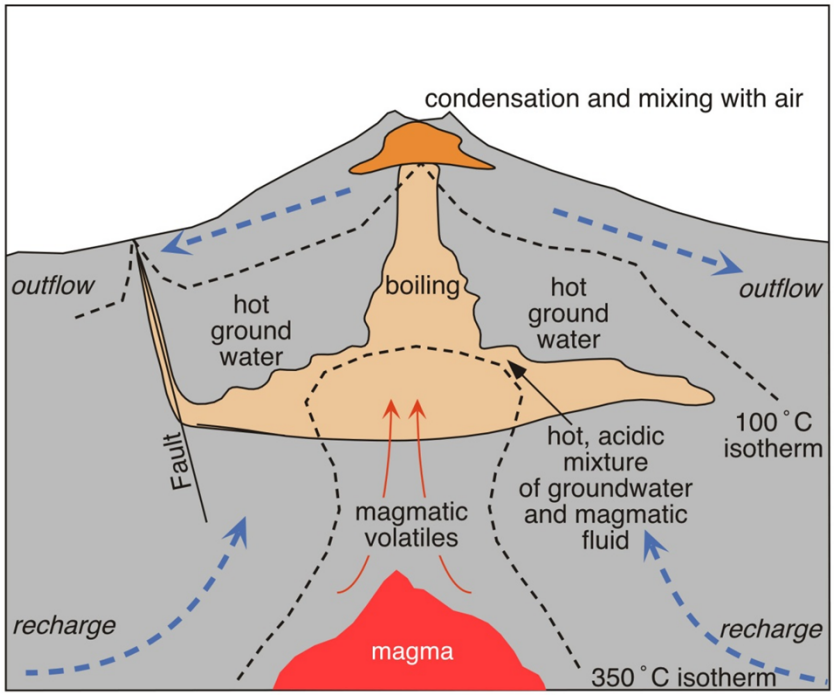
- Geologically?
  - Observational evidence for surface volcanic flows as recently as several million years ago.
    - As good as today in the geological timeframe.
  - Observational evidence for contemporary surface water flow.



- Biologically?
  - Life has been found to be very persistent if conditions are at all hospitable to the existence of life.
  - If Mars ever supported life, there still may exist oases, albeit below the surface, that are habitable and inhabited.

2016 ExoMars/TGO

Life detection via atmospheric composition analysis

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ICARUS 7, 149–159 (1967)

Life Detection by Atmospheric Analysis

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Communicated by Lewis D. Kaplan

Received December 16, 1966

Living systems maintain themselves in a state of relatively low entropy at the expense of their nonliving environments. We may assume that this general property is common to all life in the solar system. On this assumption, evidence of a large chemical free energy gradient between surface matter and the atmosphere in contact with it is evidence of life. Furthermore, any planetary biota which interacts with its atmosphere will drive that atmosphere to a state of disequilibrium which, if recognized, would also constitute direct evidence of life, provided the extent of the disequilibrium is significantly greater than abiological processes would permit. It is shown that the existence of life on Earth can be inferred from knowledge of the major and trace components of the atmosphere, even in the absence of any knowledge of the nature or extent of the dominant life forms. Knowledge of the composition of the Martian atmosphere may similarly reveal the presence of life there.

Remote detection of life on another planet was considered over 40 years ago (at JPL in fact) and focused on the analysis of atmospheric composition. Methane was suggested to be a useful atmospheric marker of extant biology.

Modern atmospheric analysis

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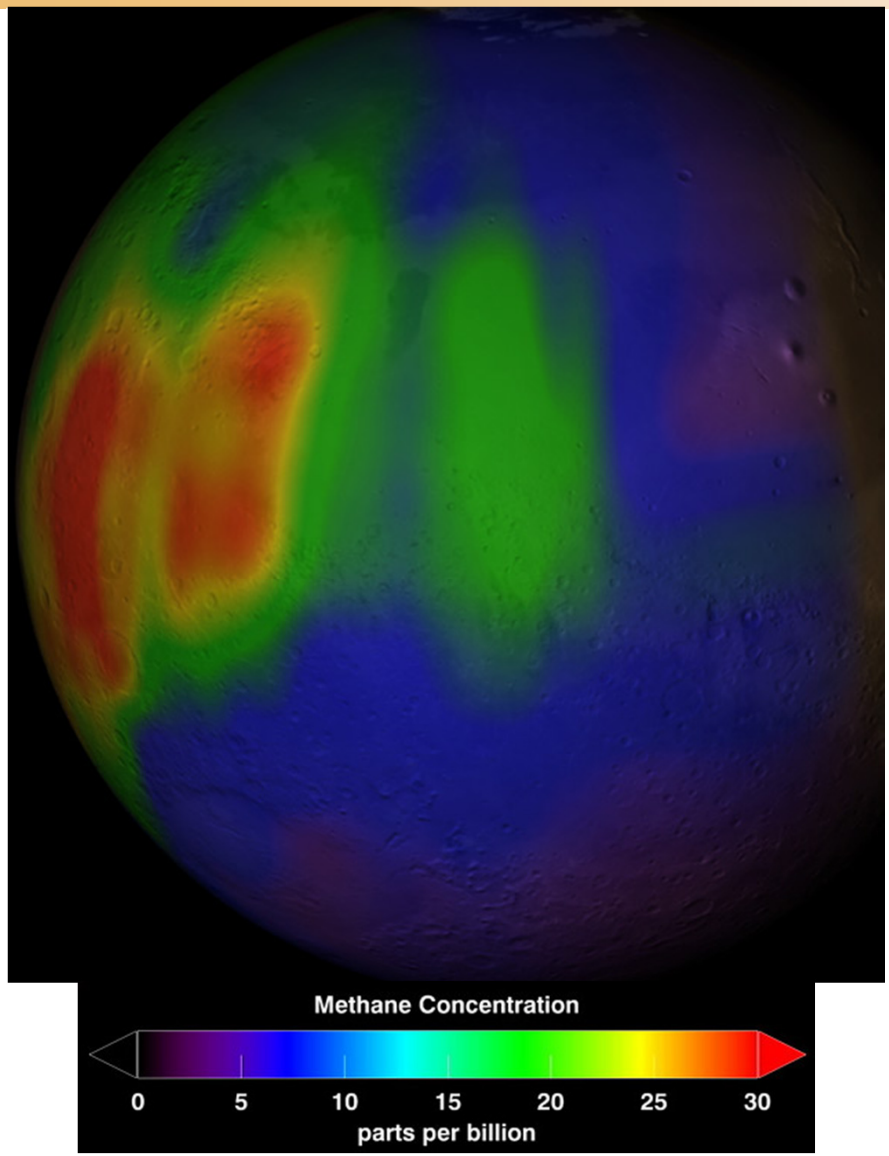

- Reported detection of methane by Mumma et al. (2009) raises the question of extant active subsurface processes on Mars, heretofore assumed not to be present
- Question: How many different subsurface processes might be active today?
- Search to answer this question not limited to methane: Must necessarily be comprehensive—a broad chemical survey that is global in scale and needs to encompass all climate seasons.

Signatures of geological activity

- Similar to terrestrial counterparts, Martian magmas expected to contain dissolved volatiles that become supersaturated during emplacement in the shallow crust or eruption. Volatiles can be transferred to the atmosphere through several processes:
  - direct degassing
  - degassing into shallow hydrothermal systems
  - interaction of rocks with hydrothermal solutions or ground waters
- Molecular composition of volatiles released from Martian magmas likely differs from terrestrial magmas and will depend on several variables
  - temperature of equilibration
    - high temperature: CO and H_2
    - low temperature: H_2S, S_2, H_2O, CH_4, NH_3
  - pressure of degassing
  - oxidation state
    - oxidized: SO_2

Signatures of biological activity

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- Terrestrial microorganisms produce a wide variety of gases as products of both energy-yielding oxidation-reduction (redox) reactions and synthesis and decomposition of organic matter
  - fermentation and anaerobic respiration under strongly reducing conditions: hydrogen-rich compounds, e.g., CH_4, NH_3, H_2S, volatile hydrocarbons, alkylated amines and sulfides
  - nitrogen redox reactions: nitrogen oxides (NO and NO_2), and N_2O
  - thermal decomposition of biogenic sedimentary organic matter: light hydrocarbons
  - microbially-mediated decomposition of sedimentary organic matter using sulfate as an oxidant: H_2S and potentially other reduced sulfur gases

ExoMars Trace Gas Orbiter (as proposed)

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- Joint European Space Agency (ESA) and National Aeronautics and Space Administration (NASA) mission
- Launch January 2016, Mars arrival October 2016, Science phase start June 2017 after final orbit achieved
- ESA contribution: 1 science instrument, spacecraft, tracking, mission operations center (entry/descent module)
- NASA contribution: 4 science instruments, ground relay, launch vehicle, tracking, science operations center

Prioritized Science Observations

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- Quantify chemical composition of trace gases, for some, with parts-per-trillion sensitivity: CO_2, CO, H_2O, H_2O_2, NO_2, N_2O, O_3, CH_4, C_2H_2, C_2H_4, C_2H_6, H_2CO, HCN, H_2S, OCS, SO_2, HCl, and isotopologues of more abundant species
  - Some relate to possible active geological and biological processes
  - Some determine atmospheric lifetimes of species released from the (sub)surface
- Characterize spatial and temporal variability
- Localize sources and sinks
  - Use observations of background state to contrain atmospheric processes
  - Use inferred winds for inverse modeling leading back to surface sources
- Use imaging to characterize surface context of regions where gases may be formed or destroyed

Proposed Payload

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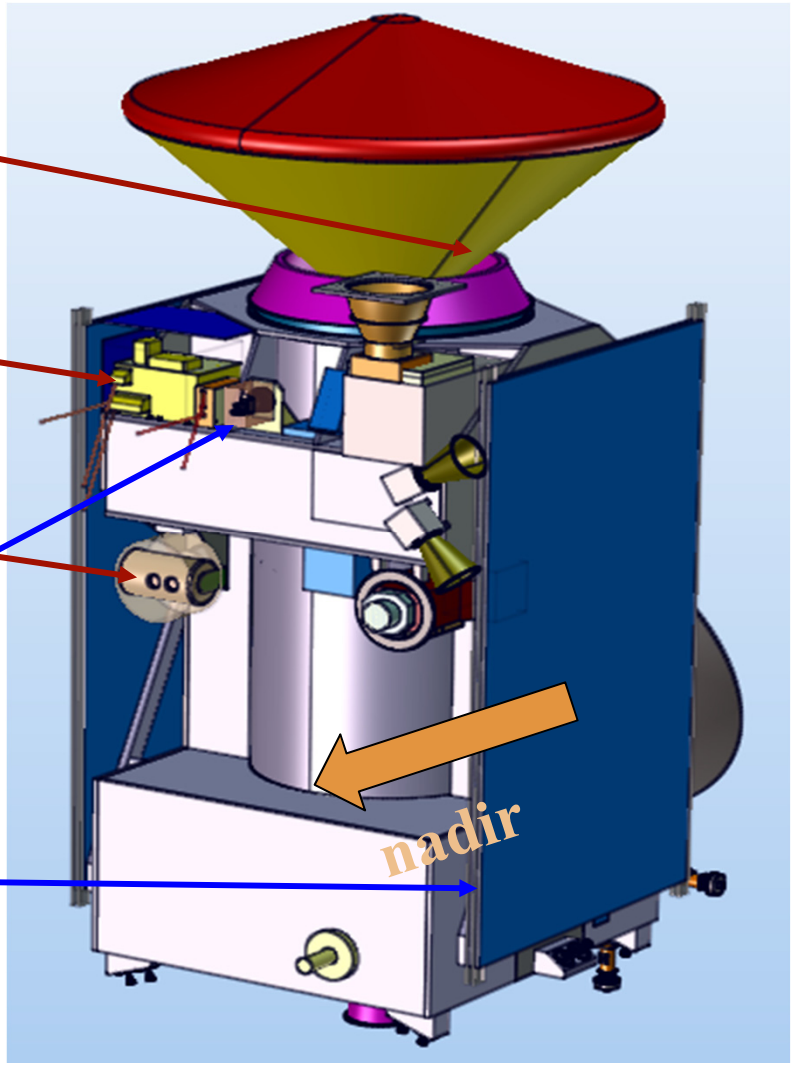
MATMOS
Solar occultation Fourier transform IR spectrometer

NOMAD
Solar occultation + mapping IR, Vis, UV spectrometer (supplied by Belgium)

EMCS
Thermal IR spectrometer

MAGIE
Wide-angle Vis-UV camera

HiSCI
High resolution, cor, stereo camera



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JPL-JG3 Is this all of the instruments?
Janis Graham, 5/18/2011

Science instrument teams

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Instrument	PI	Foreign Partner	Observing Mode
MATMOS: Mars Atmospheric Trace Molecule Occultation Spectrometer	Paul Wennberg *California Institute of Technology*	Canadian Space Agency	Solar Occultation VIS-IR
NOMAD: Nadir and Occultation Spectrometer for Mars Discovery	Ann C. Vandaele *Belgium Institute for Space Aeronomy*	Spain, Italy, UK	Solar Occultation/ Limb-nadir UV-VI-NIR
EMCS: ExoMars Climate Sounder	J. Tim Schofield *Jet Propulsion Laboratory*	Oxford U.	Limb-nadir Thermal IR
MAGIE: Mars Atmospheric Global Imaging Experiment	Bruce Cantor *Malin Space Science Systems*	n.a.	Daily Global Imager 2 UV + 2 VIS bands
HiSCI: High-resolution Stereo Color Imager	Alfred McEwen *University of Arizona*	University of Bern (Switzerland)	Stereo imager ~2 m/pixel 2 vis + 2 NIR colors

Solar occultation: signature science measurement

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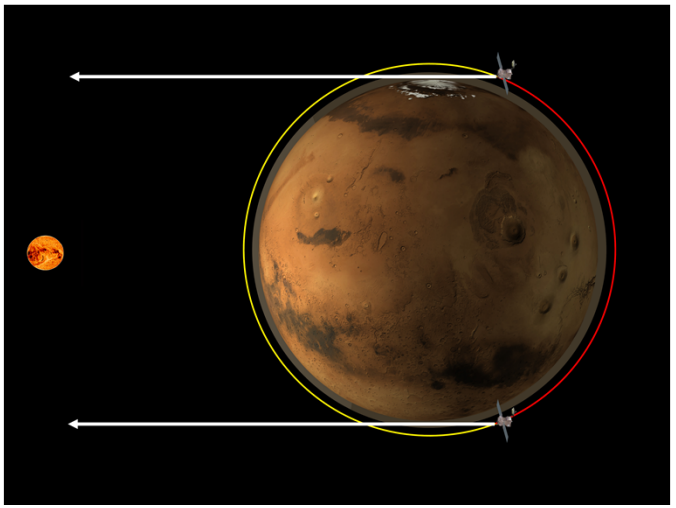
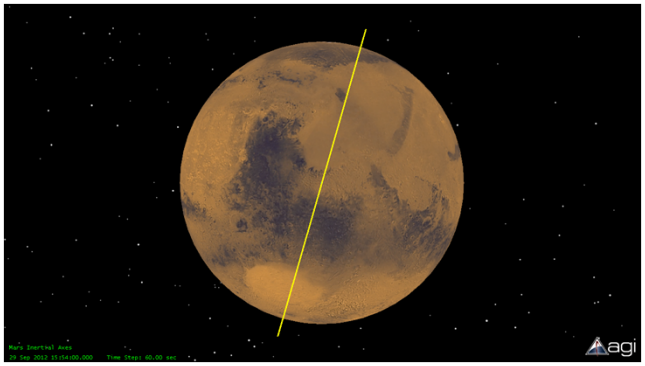
- Two solar occultations on every orbit (most of mission)
  - Bright light source
  - Long sample cell
  - 2 latitudes sampled every orbit
- Orbit inclination: 74º
  - Unique for NASA Mars orbiters to date
  - Rapid latitude variation for solar occultations
  - Rapid solar local time on surface for nadir observations





Pictures being edited

MATMOS ultrahigh sensitivity

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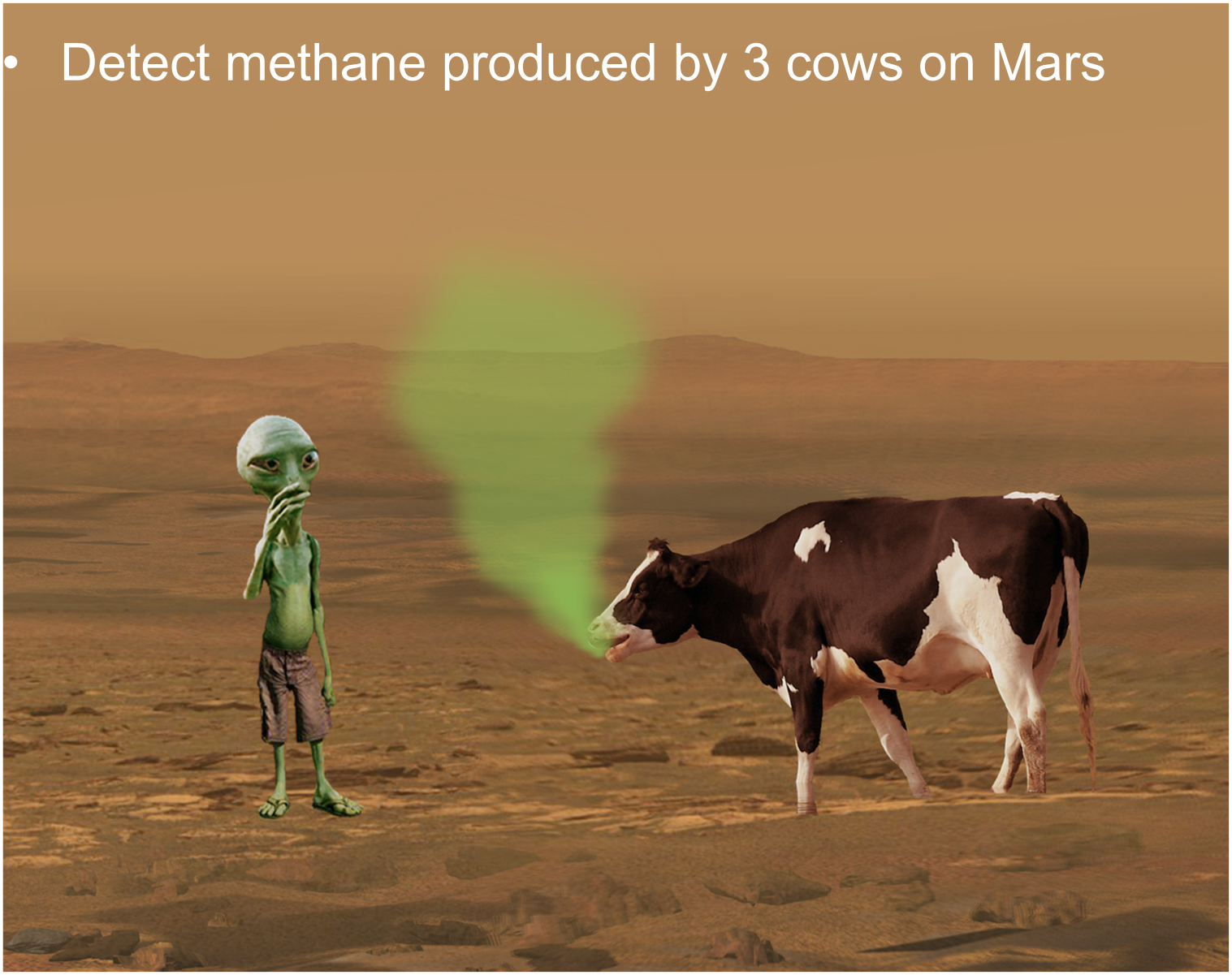
- Detect methane produced by 3 cows on Mars



NOMAD multi-spectrometer

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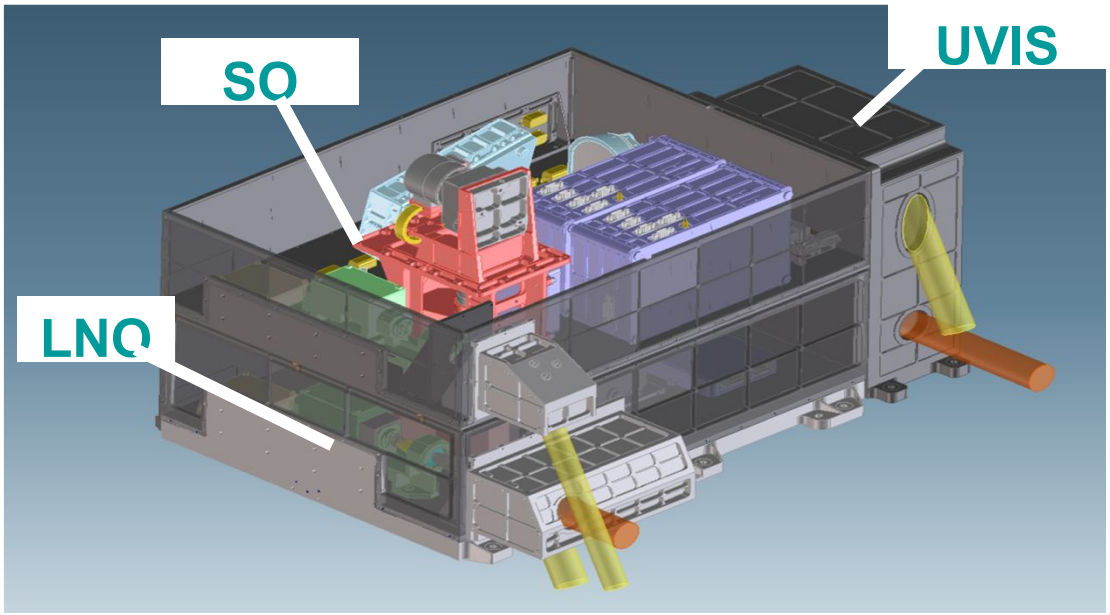
- Solar occultation spectrometer (backup redundancy with MATMOS)
  - vertical resolution ~1 km
- Limb, nadir, occultation spectrometer



- Ultraviolet/visible spectrometer
  - limb and nadir modes
  - extends dust measurements from IR to UV
    - Improved characterization of dust/ice composition, size, spatial distribution

NOMAD mapping

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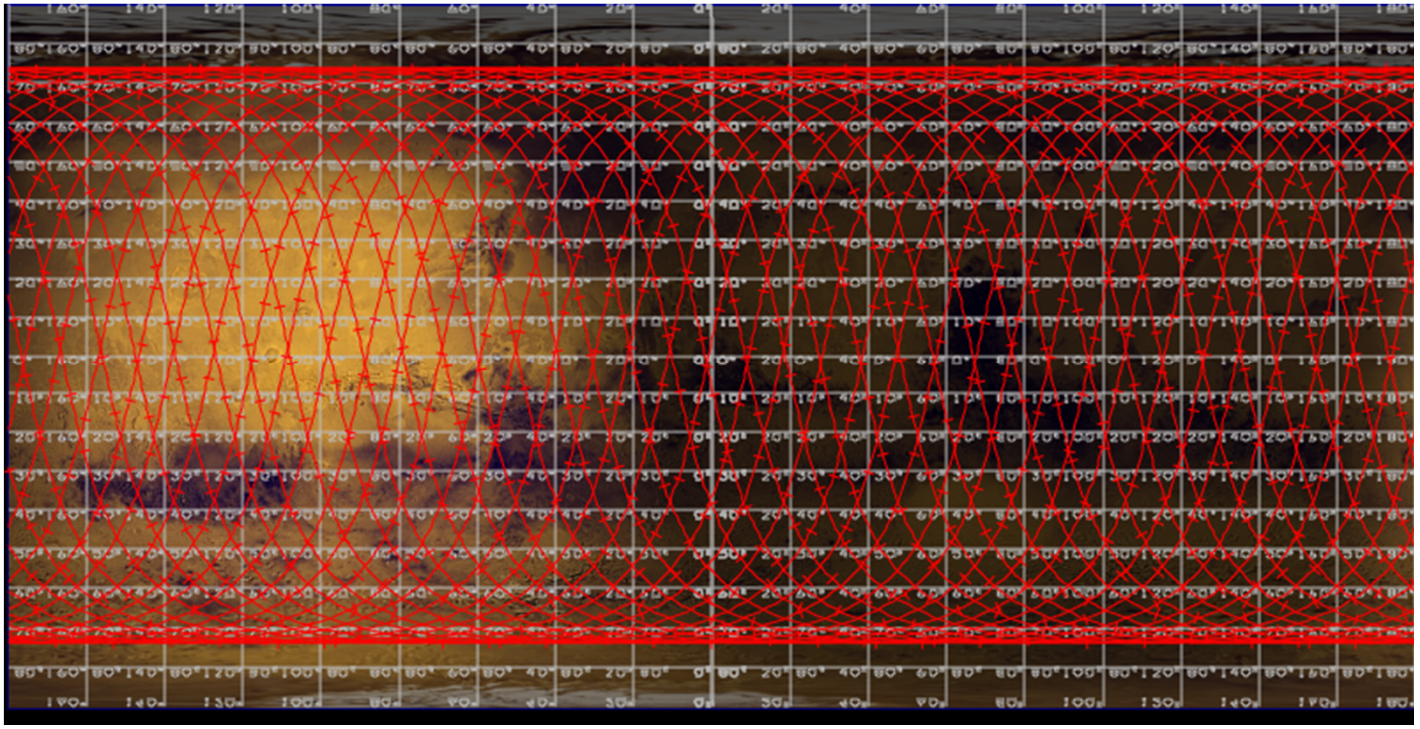
- LNO footprint at nadir (400 km altitude): 0.28 square degrees
  - Mumma et al. published methane plume: ~3600 square degrees
- 3-day nadir coverage:



Internships & Fellowships at JPL

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esa

http://www.jpl.nasa.gov/education/

JPL Education Office

- 27 Programs
- Summer, Fall, Spring, and Year-Round
- Under-represented student programs.
- High school, undergraduate, and graduate student programs.
- Postdocs and faculty programs.
- This summer JPL hosted 340 students.